

CRITICAL ITEMS LIST (CIL)

SYSTEM:	Pressure Vessels	FUNCTIONAL CRIT:	1
SUBSYSTEM:	LH2 Tank (SLWT)	PHASE(S):	a, b
REV & DATE:	J, 12-19-97	HAZARD REF:	S.02, S.06,
DCN & DATE:	002, 2-28-99		S.08
ANALYSTS:	H. Claybrook/J. Robinson		

FAILURE MODE: Leakage

FAILURE EFFECT: a,b) Loss of mission and vehicle/crew due to fire/explosion.

TIME TO EFFECT: Seconds

FAILURE CAUSE(S):
 A: Structural Failure of Plates
 B: Structural Failure of Forgings
 C: Structural Failure of Extrusions
 D: Structural Failure of Welds

REDUNDANCY SCREENS: Not Applicable

FUNCTIONAL DESCRIPTION: Contains the LH2 fuel for the SSME's.

<u>FMEA ITEM CODE(S)</u>	<u>PART NO.</u>	<u>PART NAME</u>	<u>QTY</u>	<u>EFFECTIVITY</u>
6.2.1.1	80904000000-500	LH2 Tank Complete	1	LWT-89 thru 599

REMARKS: Retention rationale for FMEA Item Codes 6.2.1.1 and 6.2.1.2 is the same.

CRITICAL ITEMS LIST (CIL)

SYSTEM:	Pressure Vessels	FUNCTIONAL CRIT:	1
SUBSYSTEM:	LH2 Tank (SLWT)	PHASE(S):	a, b, c
REV & DATE:	J, 12-19-97	HAZARD REF:	S.02, S.08
DCN & DATE:	002, 2-28-99		
ANALYSTS:	H. Claybrook/J. Robinson		

FAILURE MODE: Burst

FAILURE EFFECT: a,b) Loss of mission and vehicle/crew due to structural failure or fire/explosion.
 c) Loss of mission and vehicle/crew due to Orbiter/ET collision.
 Loss of life due to ET impacting outside designated footprint.

TIME TO EFFECT: Seconds

FAILURE CAUSE(S): A: Structural Failure of Plates
 B: Structural Failure of Forgings
 C: Structural Failure of Extrusions
 D: Structural Failure of Welds

REDUNDANCY SCREENS: Not Applicable

FUNCTIONAL DESCRIPTION: Contains the LH2 fuel for the SSME's.

<u>FMEA ITEM CODE(S)</u>	<u>PART NO.</u>	<u>PART NAME</u>	<u>QTY</u>	<u>EFFECTIVITY</u>
6.2.1.2	80904000000-500	LH2 Tank Complete	1	LWT-89 thru 599

REMARKS: Retention Rationale for FMEA Item Codes 6.2.1.1 and 6.2.1.2 is the same.

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE:

RATIONALE FOR RETENTION

DESIGN:

The Liquid Hydrogen (LH2) tank is a thin-wall fusion welded aluminum semi-monocoque shell and is designed as a safe life structure. Structural integrity is assured by the fracture control plan (MMC-ET-SE13). Materials and processes are selected in accordance with MMC-ET-SE16, which assures repetitive conformance of composition and properties. Two material specifications have been approved and added to SE16 as follows: STM11A1 for AL2195 plates and STM31A1 for extrusions. Aluminum lithium alloys offer several benefits to the SLWT design over the LWT alloys: higher strength, lower density and higher modulus. These improved material characteristics of AL2195 allowed the SLWT to be designed to meet weight reduction goals without sacrificing mission success. Aluminum Lithium material used on the LH2 tank must meet the requirements of Material Specifications STM11A1 (AL2195 Plate Products) and STM31A1 (AL2195 Extruded Products).

Other process specifications involving fabrication, testing and welding of AL2195 are contained in SE16. These specifications are STP1006 (frame chords), STP1007 (dome caps), STP1008 (dome and ogive gores), STP1010 (LH2 barrel panels), STP5507 (fusion welding), STP5508 (VPPA welding) and STP5509 (SPAU welding).

The LH2 tank is designed to a required yield safety factor of 1.10 for all loads and ultimate safety factor of 1.25 for well-defined loads (i.e. thrust, inertia from thrust, dead weight, and ullage pressure) and 1.40 for other loads (i.e. thermal, aerodynamic, and dynamic transients). However, from External Tank (ET)/Orbiter separation through Main Engine Cut-Off (MECO) +225 seconds, the assembly is designed to a required ultimate safety factor of 1.00 for all loads. Tank strength analysis is based on minimum drawing thicknesses and the minimum strength of a repaired weld (Reference ET Stress Report B26-2188).

A: The twelve forward dome gores (nine configurations) are stretch-formed per STP1008 to the required 0.75 height-to-radius ellipsoidal shape. Artificial aging to AL2195-T8A7 condition is followed by chem-milling per STP5014 on both sides to the required thicknesses. Three forward dome gores have locally thickened skin pads for the attachment of either exterior support brackets for the Gaseous Hydrogen (GH2) pressurization line, an exterior support bracket for the vent/relief duct, or interior support brackets for the sensor mast. Weld lands are configured to minimize discontinuity stresses. The dome gores are edge trimmed during assembly.

The twelve aft dome gores are stretch-formed to the required 0.75 height-to-radius ellipsoidal shape. Eleven (eight configurations) of the twelve are formed per STP1008 and artificially aged to AL2195-T8A7 condition followed by chem-milling per STP5014 on both sides to the required thicknesses. One of the gores is stretched formed per STP1002 and heat treated to the 2219-T87 condition followed by chem-milling per STP5014 on both sides to the required thicknesses. Cutouts are provided in this aft dome gore for the feedline fitting and the recirculation fitting. Weld lands are configured to minimize discontinuity stresses. The dome gores are edge trimmed during assembly.

The electrical fitting is 13.0 inches in diameter and is machined from AL2219-T87 aluminum plate. The fitting contains external mounting provisions for the electrical feedthru of the internal cabling on the sensor mast. The electrical fitting is edge trimmed during assembly. Threaded inserts and bolts are installed in the electrical fitting per STP2024 and STP2014 respectively.

The vent valve fitting is 15.0 inches in diameter and is machined from AL2219-T87 aluminum plate. The vent valve fitting provides the external mounting surface for the vent/relief valve. The vent valve fitting is edge trimmed during assembly. Threaded inserts and bolts are installed in the vent valve fitting per STP2024 and STP2014 respectively.

The forward dome and aft dome manhole fittings are 45.0 inches in diameter and are machined from AL 2219-T87 aluminum plate. The manhole fittings provide a 36.0 inch clear access to the tank interior. The manhole fittings are edge trimmed during assembly. Threaded inserts and bolts are installed in the manhole fittings per STP2024 and STP2014 respectively.

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE:

RATIONALE FOR RETENTION

DESIGN: Cont.

The forward dome spherical cap is 140.0 inches in diameter and is spin-formed per STP1005. Heat treatment to AL2219-T87 condition is followed by chem-milling per STP5014 on both sides to the required thicknesses. Cutouts are provided in the forward dome cap for the vent, electrical, and manhole fittings. The forward dome cap has locally thickened skin pads for the attachment of exterior support brackets for the GH2 pressurization line, an exterior support bracket for the vent/relief duct, and interior support brackets for the sensor mast. Weld lands are configured to minimize discontinuity stresses. The forward dome cap is edge trimmed during assembly.

The forward and aft dome manhole covers are machined from AL2219-T87 plate. The manhole covers provide a closure for and a sealing surface with the manhole fittings. The manhole covers and the manhole fittings have index pins that preclude the possibility of interchanging the Liquid Oxygen (LO2) and LH2 manhole covers. The forward dome manhole cover contains external mounting provisions for the GH2 pressurization line and the GH2 diffuser. Threaded inserts and bolts are installed in the manhole covers per STP2024 and STP2014 respectively.

The aft dome spherical cap is 140.0 inches in diameter and is spin formed per STP1007. Heat treatment to AL2195-T8Z6 condition is followed by chem-milling per STP5014 on both sides to the required thicknesses. Cutouts are provided in the aft dome cap for the siphon closure plate and manhole fitting. Weld lands are configured to minimize discontinuity stresses. The aft dome cap is edge trimmed during assembly.

The LH2 aft dome manhole cover retains the LWT configuration but the former siphon support fitting, cover and attaching fasteners were eliminated for weight savings. They were replaced with an AL2219 siphon closure plate which is now welded to the aft dome cap itself. The siphon closure plate has an approximately 4.0 inch diameter hole used for securing the plate during weld. The hole is subsequently closed with an AL2219 cap and Raco seal after welding.

Each of the four barrels is composed of eight integrally machined orthogrid configuration barrel panels pre-formed to the required radius of 165.5 inches. The panels are machined from AL2195 plate stock using numerically controlled skin mills. The panels are formed and aged per STP1010 with a final temper of T8M4. After aging, each panel is penetrant inspected and a coupon is tested for correct mechanical properties. The orthogrid configuration (integrated longitudinal and circumferential ribs) of the SLWT LH2 barrel panels enhances the structural capability of the tank. This extra capability allows for a reduction in the panel skin membrane thickness plus the deletion of internal Z-frames without sacrificing tank structural integrity. The eight panels are welded into a complete barrel assembly on the existing T04A5015 Barrel Weld Tool for Barrel 1 and T04A5016 Barrel Weld Tool for Barrels 2 through 4. These tools were modified to accommodate the orthogrid configuration and to provide the backside shielding required to weld aluminum lithium alloy. One panel from each of the four barrels has bosses machined into the orthogrid configuration for external mounting provisions of the GO2 and GH2 pressurization lines and electrical cable tray. Two panels from Barrel No. 4 have bosses machined into the orthogrid configuration for internal mounting provisions of station 1129.9 frame stabilizers. Eight panels from Barrel No. 1 have bosses machined into the orthogrid configuration for mounting provisions of the station 1973.5 frame and of the station 1871 and station 2058 frame stabilizers. One panel from Barrel No. 1 has bosses to provide an external mounting surface for a LO2 feedline support bracket. Weld lands are configured to minimize discontinuity stresses. The barrel panels are edge trimmed during assembly. Threaded inserts and bolts are installed in the required barrel panels per STP2024 and STP2014 respectively.

B: The two longerons are machined from aluminum forgings heat-treated to 2219-T6 condition. Each longeron is approximately 177.5 inches long and 32.5 inches wide and is an integral part of Barrel No. 1. The forward end of each longeron contains exterior mounting provisions for the Orbiter thrust struts. One longeron contains exterior mounting provisions for the electrical feedthru of the internal LH2 sensor cabling. The longerons are edge trimmed during assembly. Threaded inserts and bolts are installed in the longerons per STP2024 and STP2014 respectively.

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 002, 2-28-99

RATIONALE FOR RETENTION

DESIGN: (cont)

The feedline fitting is machined from a 2219-T6 aluminum forging and has a 16.60 inch inside diameter. The feedline fitting provides both an internal and external mounting surface for the feedline. The feedline fitting is edge trimmed during assembly. Threaded inserts and bolts are installed in the feedline fitting per STP2024 and STP2014 respectively.

The recirculation fitting is machined from a 2219-T6 aluminum forging and has a 3.95 inch inside diameter. The recirculation fitting carries warm LH2 from the Space Shuttle Main Engines (SSME's) back to the ET during propellant loading and hold. The recirculation fitting is edge trimmed during assembly. Threaded inserts and bolts are installed in the recirculation fitting per STP2024 and STP2014 respectively.

C: For LWT-89 thru 98, the forward dome ring is made up of three 2L2062 extrusions and one 2L2061 extrusion with all four formed per STP1006 to the required radius of 165.5 inches. Heat treatment to Al2195-T8A3 condition (STP1006) is followed by machining. It forms a portion of the LH2 tank wall, the outer chord for the station 1129.9 frame, and the interface flange to mate the LH2 tank/Intertank. The 2L2061 extrusion provides an exterior mounting surface for the ET/Orbiter forward attach fittings and a LO2 feedline support bracket. Threaded inserts and bolts are installed in the 2L2061 extrusion per STP2024 and STP2014 respectively.

For LWT-99 thru 599, the forward dome ring is made up of three 2L2094 extrusions and one 2L2093 extrusion with all four formed per STP1002 to the required radius of 165.5 inches. Heat treatment to 2219-T8511 condition is followed by machining. This ring forms a portion of the LH2 tank wall, the outer chord for the station 1129.9 frame, and the interface flange to mate the LH2 tank/Intertank. The 2L2093 extrusion provides an exterior mounting surface for the ET/Orbiter forward attach fittings and a LO2 feedline support bracket. Threaded inserts and bolts are installed in the 2L2093 extrusion per STP2024 and STP2014 respectively.

For LWT-89 and 90, Rings No. 2 (station 1377.35) and No. 3 (station 1623.80) are each made up of three 2L2069 extrusions and one 2L2059 extrusion with all four formed per STP1006 to the required radius of 165.5 inches. Heat treatment to Al2195-T8A3 condition is followed by machining. These rings form a portion of the LH2 tank wall. The 2L2059 extrusions each provides an exterior mounting surface for a LO2 feedline support bracket. Threaded inserts and bolts are installed in the 2L2059 extrusion per STP2024 and STP2014 respectively.

For LWT-91 thru 599, Ring No. 2 and No. 3 are each made up of four extrusions formed per STP1002 to the required radius of 165.5 inches. For LWT-91 thru 95, there are three 2L2007 extrusions and one 2L2006 extrusion. For LWT-96 thru 599, there are three 2L2096 extrusions and one 2L2095 extrusion. Heat-treatment to 2219-T8511 condition is followed by machining. These rings form a portion of the LH2 tank wall. The 2L2006 and 2L2095 extrusions each provide an exterior mounting surface for a LO2 feedline support bracket. Threaded inserts and bolts are installed in the 2L2006 and 2L2095 extrusions per STP2024 and STP2014 respectively.

Ring No. 1 (station 1871.00) is made up of four extrusions formed per STP1002 to the required radius of 165.5 inches. Heat treatment to 2219-T8511 condition is followed by machining. It forms a portion of the LH2 tank wall and the outer chord for the station 1871 frame. For LWT-89 and 90, there are two 2L2037 extrusions and two 2L2038 extrusions. For LWT-91 thru 95, there are two 2L2037 extrusions and two 2L2081 extrusions. For LWT-96 thru 599, there are two 2L2080 extrusions and two 2L2081 extrusions. The 2L2038 and 2L2081 extrusions provide an exterior mounting surface for a LO2 feedline support bracket. Threaded inserts and bolts are installed in the 2L2038 and 2L2081 extrusions per STP2024 and STP2014 respectively.

The aft dome ring is made up of four extrusions formed per STP1002 to the required radius of 165.5 inches. For LWT-89 thru 97, there are two 2L2016 extrusions and two 2L2017 extrusions. For LWT-98 there are two 2L2016 extrusions and two 2L2083 extrusions. For LWT-99 there are two 2L2082 extrusions and two 2L2017 extrusions. For LWT-100 thru 599, there are two 2L2082 extrusions and two 2L2083 extrusions. Heat-treatment to 2219-T8511 condition is followed by machining. The ring forms a portions of the LH2 tank wall, the outer chord for the station 2058 frame, and provides an exterior mounting surface for the ET/Orbiter aft attach fittings, the ET/Solid Rocket Booster (SRB) aft attach fittings, the GO2 pressurization line, and transportation fittings. Threaded inserts and bolts are installed per STP2024 and STP2014 respectively.

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank(SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 005, 6-30-00

RATIONALE FOR RETENTION

DESIGN: (cont)

D: The LH2 tank welds are designed to a safe life criterion. This assures that failure will not occur from flaw propagation in the expected operating environment during the required life of the vehicle. The welds are designed to three criteria: 1) leak-burst fracture stress, 2) allowable weld grades, and 3) allowable ultimate strength.

Various welding processes are used on the LH2 tank: Fusion (TIG) Welding, Variable Polarity Plasma Arc (VPPA) welding and Soft Plasma Arc Welding (SPAW). The requirements for these welds are controlled by STP5501/STP5507, STP5506/STP5508 and STP5509, respectively. STPs 5501 and 5506 are used exclusively for AL2219/AL2219 aluminum alloy. STPs 5507, 5508 and 5509 are used to weld AL2195/AL2195, AL2195/AL2219 aluminum combinations and AL2219/AL2219 segments when included as partial joint lengths in preceding weld combinations. After completion of welding, every weldment is visually and non-destructively inspected. Friction plug welding can be used to repair 2195/2195 and 2195/2219 aluminum weld combinations. This weld repair process is controlled by STP 5510. All repair/rework of AL2195 welds shall be reviewed for final acceptance by the Material Review Board with work performed and controlled by established weld repair procedures.

Radiographic inspection of initial AL2195 welds are conducted to established LWT ET practices. Heat repair welds require "angle shots" taken at $\pm 35^\circ$ off the 90° angle in addition to the conventional 90° angle perspective. Angle shots are also taken of weld intersections and weld start/stop locations. The LH2 tank welds are designed to a safe life criterion. This assures that failure will not occur from flaw propagation in the expected operating environment during the required life of the vehicle. The welds are designed to three criteria: 1) leak-burst fracture stress, 2) allowable weld grades, and 3) allowable ultimate strength.

TEST:

The LH2 Tank Complete is certified for SLWT. Reference HCS MMC-ET-TM08-L-S503.

Verification:

SLWT LH2 tank structural verification was tied to either a test or LWT flight history. Test and flight data from the Standard Weight Tank (SWT) and current LWT program influenced the SLWT design in areas where testing was impractical. SLWT thicknesses remained the same as LWT in these areas and existing ringframe stiffness was maintained to protect applicability of SWT stability testing. Verification tests on the LH2 tank included the Aluminum Lithium Test Article (ALTA), component, material, coupon, protoflight and proof. The analytical methods that were used for verification were validated by correlation to SWT, LWT and SLWT test programs. In addition to the above verification activities, all aspects of SLWT ground operations are planned to be tested by a special tanking test on LWT-89 (SLWT Tanking Test).

A-D: SLWT Tanking Test (LWT-89 only)

This test will demonstrate (1) overall thermal and structural response to cryogenic loading, and (2) LH2 tank aft dome stability for ambient and cryogenic prelaunch limit load conditions.

A-D: ALTA Proof and Stability Test (Report MMC-ET-SF63-01)

ALTA contained a barrel section representative of LH2 tank barrels 3 and 4, as well as the panels on the $\pm X$ and $\pm Y$ axis of barrels 1 and 2. Test data from ALTA validated analytical methods used to design the SLWT and demonstrated strength of LH2 barrels and stability capability of the LH2 Tank orthogrid panels.

Component Tests:

A-D: Barrel Panel Component Hoop Tension Test (Report 826-3000-10)

The analytical methods used in the strength analysis of the orthogrid panel configuration were verified by this test. The test article simulated the critical LH2 barrel AL4043 weld and was representative of the thinnest membrane on ALTA and SLWT.

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 001, 6-15-98

RATIONALE FOR RETENTION

TEST: (cont)

A-D: Barrel Panel Component Compression Test (Report MMC-ET-SE63-2)

The analytical methods used in the stability analysis of the orthogrid panel configuration were verified by this test. The test articles consisted of two 48 inch x 48 inch butt-welded orthogrid panels.

A-D: Cryogenic Environments Tests (Reports MMC-ET-SE63-10 and-11)

These tests demonstrated the capability of the longitudinal LH2 orthogrid welds (Al2195 to Al2195) and alternate blowing agent foam NCFI 24-124 (1X) to withstand 125% flight limit loads at cryogenic substrate temperature and acoustics.

D: Fillet Weld Test (Report MMC-ET-SE63-7)

Cable trays and pressline supports are fillet welded to the LH2 tank. This test demonstrated fillet welding on Al2195 base metal and the interaction of parent metal with clip stresses at these welds.

A,C: Biaxial Failure Theory Test (Report MMC-ET-SE63-8)

Biaxial failure effects tests verified the failure theory methodology used for the strength analysis.

A-D: Stress Concentration/Insert Pull Tests (Reports 826-2483 and MMC-ET-SE63-10)

Stress concentration tests were performed to address Al2195 elongation results on design. Three main regions (thin plate, thick plate, and inserts) were tested. No issues were identified by these tests.

Material/Weld Coupon

A,C: Aluminum-Lithium Lot Acceptance Test Methods and Requirements (MMC-ET-SE59)

Lot Acceptance Test (LAT) and Characterization programs for Al2195 Plate and Extrusions were conducted concurrently. The material procurement specifications (STM11A1 and STM31A1) specified comprehensive lot acceptance test programs which verify that each Al2195 plate and extrusion meet minimum material property requirements. These test programs, documented in MMC-ET-SE59, have been approved by NASA. These LAT processes ensures that all Al2195 material meets the minimum design strength and fracture toughness. Only material that meets SE59 requirements is used on SLWT and ALTA.

D: SLWT LH2 tank welding was verified by the development of welding allowables for each weld joint configuration and the inspection of each flight weld. Each new weld process is controlled by a STP identified in MMC-ET-SE16. This weld development work assures that these STPs (5507, 5508 and 5509) meet the EIS requirement. All welded flight hardware drawings must reference these STPs and are approved by materials engineering.

A,C,D: Al-Li Materials Data Base (Service Order 89818)

This service order documents the test data used to develop the design values (allowables) for Al2195. Test data from the following six areas is included:

1. Plate allowables including
Alternate Fracture Toughness Ratio Determination
Simulated Service Testing
Fatigue Crack Propagation Rate Determination
2. Extrusion Allowables
3. Weld Allowables including
Initial Weld Tensile Allowables
Initial Weld Fracture Allowables
Repair Weld Fracture Testing
Effect of Peaking and Mismatch
Wide Panel Test Results

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 001, 6-15-98

RATIONALE FOR RETENTION

TEST: (cont)

4. First Article Cut-Up Testing
5. Processing Development at Vendors
6. Physical Property Determination

Acceptance:

MAF:

- D: Perform protoflight test to verify stability (MMC-ET-TM04k and 80914002518).
The LH2 protoflight test provides confidence with a stability test for 115% of critical design limit loads. Multiple load cases at various pressure settings verifies barrel panels and aft dome. This test simulates orbiter point loads not tested by ALTA.
- A-D: Perform LH2 tank proof test to verify structural integrity and ultimate cycle life (MMC-ET-TM04k and 80914002518).
The SLWT proof test applies the same philosophy as SWT and LWT. The test is fracture based and proves that any undetected flaw will not grow enough to cause a failure within four mission lifes of the tank. Post proof Non-Destructive Evaluation (NDE) is performed on all inadequately proofed welds.
The required proof stress is equal to the flight limit stress multiplied by the proof factor at the proof test temperature. This proof factor is equal to the fracture toughness of the material at the proof test temperature divided by the fracture toughness of the material at the use temperature times the proof factor at the use temperature.
Test covers are substituted for the forward and aft dome manhole flight covers for proof test. The test covers have the same elastic properties and the same equivalent stiffness as the flight covers. The flight covers are proof tested separately to facilitate manufacturing.
- D: Inadequately proofed and manual welds that form a part of the pressure vessel wall are identified in the "Weld Acceptance Manual" (8090000069). Welds are considered inadequately proofed when the temperature adjusted load during proof testing is less than the load during flight multiplied by the required proof factor specified in the EIS. Structural integrity of these welds is assured by an additional NDE (radiographic examination) after proof testing per STP2503.
- A: LH2 tank parts made from Al2195 undergo penetrant inspection per STP2507. This inspection requires two certified personnel to independently inspect and document penetrant inspection results.
- D: Perform the LH2 leak test to verify structural integrity (MMC-ET-TM04k).
The LH2 tank is pressurized with G₂ to 6.0 psi after completion of the proof test. A leak test fluid is applied to the fusion butt welds to detect leaks. The system is controlled by STP3503. No leaks are permitted.

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CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION:

Vendor Inspection - Lockheed Martin Surveillance:

- A: Verify material selection and verification controls (MMC-ET-SE16, QQ-A-250/30 and STM1701 for AL2219 parts; MMC-ET-SE16 and STM11A1 for AL2195 parts).
- B: Verify material selection and verification controls (MMC-ET-SE16, STM-Q-250 and STM5163).
- C: Verify material selection and verification controls (MMC-ET-SE16 and STM3120, Class 1 for AL2219 parts; MMC-ET-SE16 and STM31A1 for AL2195 parts).
- A: Verify heat treatment of the following part to 2219-TB7 (MIL-H-6088).
- | | |
|--|-------------------------------------|
| <u>Forward Dome Cap</u>
80914150993 | <u>Aft Dome Gore</u>
80914980993 |
|--|-------------------------------------|
- A: Verify mechanical properties test for the following part (Engineering drawing and STP1007).
- | |
|------------------------------------|
| <u>Aft Dome Cap</u>
80914950991 |
|------------------------------------|
- A: Verify mechanical properties test for the following parts (Engineering drawing and STP1008).
- | | |
|--|---|
| <u>Forward Dome Gores</u>
80914160981
80914160982
80914160983
80914160984
80914160986 | <u>Aft Dome Gores</u>
80914980991
80914980994
80914980996
80914980997 |
|--|---|
- A: Verify mechanical properties test for the following parts (Engineering drawing and STP1010).
- | | |
|---|---|
| <u>Barrel #1 Panels</u>
80914800930
80914800931
80914800932
80914800933
80914800934
80914800935
80914800936
80914800937 | <u>Barrel #2 Panels</u>
80914600930
80914600931
80914600932
80914600933
80914600934
80914600936
80914600937 |
| <u>Barrel #3 Panels</u>
80914400930
80914400931
80914400932
80914400933
80914400934
80914400936
80914400937 | <u>Barrel #4 Panels</u>
80914200930
80914200931
80914200932
80914200933
80914200934
80914200935
80914200936
80914200937 |
- C: Verify mechanical properties test for the following parts (Engineering drawing and STP1006).
- | | | |
|--|--|--|
| <u>Forward Dome Ring</u>
80914140997 (LWT-89 thru 98) | <u>Ring #2 Segment</u>
80914500961 (LWT-89, 90) | <u>Ring #3 Segment</u>
80914500961 (LWT-89, 90) |
|--|--|--|

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

B: Verify heat treatment of the following part to 2219-T6 (MIL-H-6088).

Longeron
80914800987 (LWT-89, 90, 92, 97)
80914800989 (LWT-91 thru 96, 98 thru 599)
80914800990 (LWT-91, 93 thru 599)

C: Verify heat treatment of the following parts to 2219-T8511 (MIL-H-6088).

<u>Aft Dome Ring Segment</u>	<u>Ring No. 1 Segment</u>
80914960998	80914700993 (LWT-89 thru 95) 80914700994 (LWT-91 & Up)

A: Verify cleaning of the following part (STP5008 and Engineering drawing).

Diffuser Mounting Plate
80921021047

B,C: Verify ultrasonic examination of the following parts (MIL-I-8950, Class B).

<u>Aft Dome Ring</u>	<u>Ring No. 1 Segment</u>	<u>Longeron</u>
80914960998 (2L2016 and 2L2017 Only)	80914700993 (LWT-89 thru 95) (2L2037 and 2L2038 Only)	82614300026

A-C: Verify ultrasonic examination of the following parts (STM11A1 or STM31A1).

<u>Barrel No. 1 Panels</u>	<u>Barrel No. 2 Panels</u>	<u>Barrel No. 3 Panels</u>
80914800920 80914800921 80914800922 80914800923 80914800924 80914800925 80914800926 80914800927	80914600920 80914600921 80914600922 80914600923 80914600924 80914600926 80914600927	80914400920 80914400921 80914400922 80914400923 80914400924 80914400926 80914400927
<u>Barrel No. 4 Panels</u>	<u>Forward Dome Ring</u>	<u>Ring No. 2 Segment</u>
80914200920 80914200921 80914200922 80914200923 80914200924 80914200925 80914200926 80914200927	80914140997 (2L2062 and 2L2061 Only)	80914500961 (LWT-89 thru 95)
	<u>Ring No. 3 Segment</u>	
	80914500961 (LWT-89 thru 95)	

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

A: Inspect rib waviness of the following parts (Engineering drawing).

Barrel No. 1 Panels

80914800930
80914800931
80914800932
80914800933
80914800934
80914800935
80914800936
80914800937

Barrel No. 2 Panels

80914600930
80914600931
80914600932
80914600933
80914600934
80914600936
80914600937

Barrel No. 3 Panels

80914400930
80914400931
80914400932
80914400933
80914400934
80914400936
80914400937

Barrel No. 4 Panels

80914200930
80914200931
80914200932
80914200933
80914200934
80914200935
80914200936
80914200937

A-C: Inspect dimensions of the following parts (Engineering drawing).

Barrel No. 1 Panels

80914800920
80914800921
80914800922
80914800923
80914800924
80914800925
80914800926
80914800927
80914800930
80914800931
80914800932
80914800933
80914800934
80914800935
80914800936
80914800937

Barrel No. 2 Panels

80914600920
80914600921
80914600922
80914600923
80914600924
80914600926
80914600927
80914600930
80914600931
80914600932
80914600933
80914600934
80914600936
80914600937

Barrel No. 3 Panels

80914400920
80914400921
80914400922
80914400923
80914400924
80914400926
80914400927
80914400930
80914400931
80914400932
80914400933
80914400934
80914400936
80914400937

Barrel No. 4 Panels

80914200920
80914200921
80914200922
80914200923
80914200924
80914200925
80914200926
80914200927
80914200930
80914200931
80914200932
80914200933
80914200934
80914200935
80914200936
80914200937

Forward Dome Gores

80914160981
80914160982
80914160983
80914160984
80914160986

Aft Dome Gores

80914980991
80914980993
80914980994
80914980996
80914980997

Ring No. 1 Segment

80914700993 (LWT-89 thru 95)
80914700994 (LWT-91 & Up)

Ring No. 2 Segment

80914500961

Ring No. 3 Segment

80914500961

Aft Dome Cap

80914950991

Forward Dome Cap

80914150993

Longeron

80914800987 (LWT-89, 90, 92, 97
80914800989 (LWT-91 thru 97, 98 thru 599)
80914800990 (LWT-91, 93 thru 599)

Recirculation Fitting

80914940988

Feedline Fitting

80914940986

Forward Dome Ring

80914140997

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

<u>Electrical Fitting</u> 80914130996	<u>Siphon Support Fitting</u> 80914930988	<u>Forward Dome Manhole Fitting</u> 80914150948
<u>Aft Dome Manhole Fitting</u> 80914950994	<u>Vent Valve Fitting</u> 80914130996	<u>Diffuser Mounting Plate</u> 80921021047
<u>Aft Dome Ring</u> 80914960998	<u>Feedthru Plate</u> 80934003726 80931003717	

A-C: Inspect penetrant examination of the following parts (STP2501).

<u>Forward Dome Cap</u> 80914150993	<u>Aft Dome Ring</u> 80914960998	<u>Aft Dome Gore</u> 80914980993
<u>Siphon Support Fitting</u> 80914930988	<u>Aft Dome Manhole Fitting</u> 80914950994	<u>Longeron</u> 80914800987 (LWT-89, 90, 92, 97) 80914800989 (LWT-91 thru 96, 98 thru 599) 80914800990 (LWT-91, 93 thru 599)
<u>Recirculation Fitting</u> 80914940988	<u>Fwd Dome Manhole Fitting</u> 80914150948	<u>Diffuser Mounting Plate</u> 80921021047
<u>Siphon Closure Cap</u> 80911001445		
<u>Vent Valve Fitting</u> 80914130996	<u>Ring No. 1 Segment</u> 80914700993 (LWT-89 thru 95) 80914700994 (LWT-91 & up)	<u>Electrical Fitting</u> 80914130996
<u>Feedthru Plate</u> 80931003717 80934003726	<u>Feedline Fitting</u> 80914940986	

A,C: Inspect penetrant examination of the following parts (STP2507).

<u>Barrel #1 Panels</u> 80914800930 80914800931 80914800932 80914800933 80914800934 80914800935 80914800936 80914800937	<u>Barrel #2 Panels</u> 80914600930 80914600931 80914600932 80914600933 80914600934 80914600936 80914600937	<u>Barrel #3 Panels</u> 80914400930 80914400931 80914400932 80914400933 80914400934 80914400936 80914400937
<u>Barrel #4 Panels</u> 80914200930 80914200931 80914200932 80914200933 80914200934 80914200935 80914200936 80914200937	<u>Forward Dome Gores</u> 80914160981 80914160982 80914160983 80914160984 80914160986	<u>Aft Dome Gores</u> 80914980991 - 80914980994 80914980996
<u>Forward Dome Ring</u> 80914140997	<u>Aft Dome Cap</u> 80914950991	<u>Ring #3 Segment</u> 80914500961

A-C: Inspect hole dimensions for inserts on the following parts (STP2024 and Engineering drawing).

<u>Longeron</u> 80914800987	<u>Forward Dome Ring</u> 80914140997	<u>Ring No. 3 Segment</u> 80914500961
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CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

A-C: Inspect hole dimensions for inserts on the following parts (STP2024 and Engineering drawing).

<u>Longeron</u> 80914800987 (LWT-89, 90, 92, 97) 80914800989 (LWT-91 thru 96 98 thru 599) 80914800990 (LWT-91, 93 thru 599)	<u>Forward Dome Ring</u> 80914140997	<u>Ring No. 3 Segment</u> 80914500961
<u>Ring No. 2 Segment</u> 80914500961	<u>Ring No. 1 Segment</u> 80914700993 (LWT-89 thru 95) 80914700994 (LWT-91 & Up)	<u>Barrel No. 4 Panels</u> 80914200920 80914200921
<u>Barrel No. 3 Panel</u> 80914400920	<u>Barrel No. 2 Panel</u> 80914600920	<u>Barrel No. 1 Panels</u> 80914800920 80914800921 80914800922 80914800923 80914800924 80914800925 80914800926 80914800927
<u>Feedthru Plate</u> 80931003717	<u>Recirculation Fitting</u> 80914940988	
<u>Diffuser Mounting Plate</u> 80921021047		

A-C: Inspect part number applied to the following parts (Engineering drawing).

<u>Barrel No. 1 Panels</u> 80914800920 80914800921 80914800922 80914800923 80914800924 80914800925 80914800926 80914800927 80914800930 80914800931 80914800932 80914800933 80914800934 80914800935 80914800936 80914800937	<u>Barrel No. 2 Panels</u> 80914600920 80914600921 80914600922 80914600923 80914600924 80914600926 80914600927 80914600930 80914600931 80914600932 80914600933 80914600934 80914600936 80914600937	<u>Barrel No. 3 Panels</u> 80914400920 80914400921 80914400922 80914400923 80914400924 80914400926 80914400927 80914400930 80914400931 80914400932 80914400933 80914400934 80914400936 80914400937
<u>Barrel No. 4 Panels</u> 80914200920 80914200921 80914200922 80914200923 80914200924 80914200925 80914200926 80914200927 80914200930 80914200931 80914200932 80914200933- 80914200934 80914200935 80914200936 80914200937	<u>Forward Dome Gores</u> 80914160981 80914160982 80914160983 80914160984 80914160986	<u>Aft Dome Gores</u> 80914980991 80914980993 80914980994 80914980996 80914980997

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

B: Verify cold cycle stress relief on the following part (Engineering drawing).

Feedline Fitting
80914940986

A: Verify chemical film applied to the following parts (STP3001, Class 1A and Engineering drawing).

Feedthru Plates
80934003726
80931003717

Diffuser Mounting Plate
80921021047

Siphon Closure Cap
80911001445

A: Verify epoxy primer applied to the following parts (STP3003, Type 1 and Engineering drawing).

Feedthru Plates
80934003726
80931003717

Diffuser Mounting Plate
80921021047

Siphon Closure Cap
80911001445

Lockheed Martin Procurement Quality Representative:

A: Witness Proof Test of the following parts (Engineering drawing).

Feedthru Plates
80934003726
80931003717

MAE Quality Inspection:

A: Verify material selection and verification controls of the following parts (MMC-ET-SE16 and STM11A1).

Forward Dome Manhole Cover
80914081488

Aft Dome Manhole Cover
80911001444

A: Inspect dimensions of the following parts (Engineering drawing).

Electrical Fitting
80914110990

Forward Dome Manhole Fitting
80914110990

Vent Valve Fitting
80914110990

Siphon Support Fitting
80914910990

Aft Dome Manhole Fitting
80914910990

Feedline Fitting
80914961960

Aft Dome Manhole Cover
80911001444

Forward Dome Manhole Cover
80914081488

A: Verify cleaning of the following parts (STP5008 and Engineering drawing).

Forward Dome Manhole Cover
80914081488

Aft Dome Manhole Cover
80911001444

Feedthru Plates
80934003709
80931003779

A: Verify epoxy primer applied to the following parts (STP3003, Type 1 and Engineering drawing).

Forward Dome Manhole Cover
80914081488

Aft Dome Manhole Cover
80911001444

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

RATIONALE FOR RETENTION

INSPECTION: (cont)

A: Inspect weld land widths of the following assemblies (Engineering drawing).

<u>Forward Dome Assembly</u>	<u>Aft Dome Assembly</u>
80914100995	80914900980
80914120900	80914920900
80914140975	80914941979
80914140985	80914970940
80914140995	80914970955
80914160925	80914980935
80914160935	80914980945
80914160945	80914980955
80914170910	
80914170925	

A-C: Inspect hole dimensions for inserts on the following parts (STP2024 and Engineering drawing).

<u>Forward Dome Manhole Cover</u>	<u>Aft Dome Ring</u>	<u>Aft Dome Manhole Fitting</u>
80914081488	80914961960	80914910990
<u>Feedline Fitting</u>	<u>Forward Dome Manhole Fitting</u>	<u>Aft Dome Manhole Cover</u>
80914961960	80914110990	80911001444
<u>Electrical Fitting</u>	<u>Vent Valve Fitting</u>	<u>Siphon Support Fitting</u>
80914110990	80914110990	80914910990
		80914951969

A-C: Inspect installation of bolts in the following parts and assemblies (STP2014 and Engineering drawing).

<u>Aft Dome Manhole Fitting</u>	<u>Forward Dome Manhole Cover</u>	<u>Forward Dome Manhole Fitting</u>
80911001449	80924061009	80914081490
<u>Forward Dome Ring</u>	<u>Siphon Support Fitting</u>	<u>Feedthru Plates</u>
80911051109	80911001449	80931003779
80914151910	80914951969	80931003810
80911001459		
<u>Electrical Fitting</u>	<u>Diffuser Mounting Plate</u>	<u>Recirculation Fitting</u>
80931003810	80921021009	80921011009
<u>Vent Valve Fitting</u>	<u>Barrel No. 4 Assembly</u>	<u>Barrel No. 3 Assembly</u>
80921021309	80914001950	80914041409
	80914041409	
<u>Barrel No. 2 Assembly</u>	<u>Barrel No. 1 Assembly</u>	<u>Feedline Fitting</u>
80914041409	80914091989	80921011009
	80914801940	80924901916
	80914041409	
	80914041459	
<u>Ring No. 3 Assembly</u>	<u>Ring No. 2 Assembly</u>	<u>Ring No. 1 Assembly</u>
80911001459	80914041459	80914041459
<u>Aft Dome Ring Assembly</u>	<u>Longeron</u>	80914701990
80914041409	80914091979	
80911031149	80914091989	
80911031169	80934003719	
80911051120		
80911051124		

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 004, 6-30-99

INSPECTION: (cont)

RATIONALE FOR RETENTION

- A: Witness Proof Test for siphon closure cap (80911001445).
- A-D: Witness Proof Test and Leak Test (MMC-ET-TM04k).
- D: Witness Protoflight Test (80914002518).
- A-D: Verify cleaning and chemical film applied to the following assemblies (STP5009 and Engineering drawing).
LH2 Tank Assembly
 80914015920
 80914005940
- A-D: Verify chemical film applied to the following parts (STP3001, Class 1A and Engineering drawing).

<u>Forward Dome Manhole Cover</u> 80914081488	<u>Forward Dome Manhole Fitting</u> 80914110990	<u>Aft Dome Manhole Cover</u> 80911001444
<u>Forward Dome Ring</u> 80914100900	<u>Electrical Fitting</u> 80914110990	<u>Aft Dome Ring</u> 80914900900
<u>Vent Valve Fitting</u> 80914110990	<u>Aft Dome Manhole Fitting</u> 80914910990	<u>Siphon Support Fitting</u> 80914910990 80914951969
<u>Feedline Fitting</u> 80914961960	<u>LH2/Intertank Flange</u> 80911000000 80914101900	
- A-D: Verify epoxy primer applied to the following parts and assembly (STP3004 and Engineering drawing).

<u>LH2 Tank Assembly</u> 80914005940	<u>Aft Dome Ring</u> 80911000000 80914004000
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- A, C: Inspect penetrant examination of the following parts (STP2507).

<u>Aft Dome Manhole Cover</u> 80911001444	<u>Forward Dome Ring</u> 80914101900	<u>Forward Dome Manhole Cover</u> 80914081488
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- A, C: Inspect orientation of welded parts in the following assemblies (Engineering drawing).

<u>Barrel No. 4 Assembly</u> 80914200940	<u>Barrel No. 3 Assembly</u> 80914400940	<u>Forward Dome Assembly</u> 80914100900
<u>Barrel No. 2 Assembly</u> 80914680940	<u>Barrel No. 1 Assembly</u> 80914800940	
<u>LH2 Tank Assembly</u> 80914000000 80914090960		
- A, C: Inspect axis orientation markings and/or direction orientation markings applied to the following assemblies (Engineering drawing).

<u>Forward Dome Assembly</u> 80914120900	<u>Aft Dome Assembly</u> 80914920900	<u>Ring No. 3 Assembly</u> 80914300975
<u>Ring No. 2 Assembly</u> 80914500935	<u>Ring No. 1 Assembly</u> 80914700995	

CRITICAL ITEMS LIST (CIL)
CONTINUATION SHEET

SYSTEM: Pressure Vessels
SUBSYSTEM: LH2 Tank (SLWT)
FMEA ITEM CODE(S): 6.2.1.1, 6.2.1.2

REV & DATE: J, 12-19-97
DCN & DATE: 005, 6-30-00

RATIONALE FOR RETENTION

INSPECTION: (cont)

A, C: Verify zinc chromate paste applied to the following assemblies (Engineering drawing).

Ring No. 3 Assembly
80911001459

Ring No. 2 Assembly
80914041459

Ring No. 1 Assembly
80914041459

Forward Dome Ring Assembly
80911051109
80911001459

Barrel No. 4 Assembly
80914041409

Aft Dome Ring Assembly
80911051120
80911051124
80911031149
80911031169
80914041409

Barrel No. 2 Assembly
80914041409

Barrel No. 1 Assembly
80914041409
80914041459

Barrel No. 3 Assembly
80914041409

D: Inspect the 2319 aluminum weld wire/rod (MMS-Y-469) for conformance to material specification and packaging (MMC-ET-SE16 and STM-Y-469).

D: Inspect the 4043 aluminum weld wire/rod (MMS-Y-469B) for conformance to material specification and packaging (MMC-ET-SE16 and STM-Y-469B).

D: Inspect post proof inspection (Engineering drawing).

LH2 Post Proof Inspection
80914004000

D: Inspect post proof ultrasonic and penetrant inspections of friction plug weld repairs (80914004000 and STP 5510 for LWT-105 thru 599).

D: Inspect the dimensions and conformance to weld grade of the following assemblies (Engineering drawing).

Reference the following STPs for welding and acceptance requirements: STP5501(AL2219)/STP5507(AL2195) for TIG weld, STP5506(AL2219)/STP5508(AL2195) for VPPA weld and STP5509(AL2195) for SPAW weld.

Forward Dome Assembly
80914100900
80914100995
80914101900
80914120900
80914130930
80914140975
80914140985
80914140995
80914150940
80914160925
80914160935
80914160945
80914170910
80914170925

Aft Dome Assembly
80914900980
80914920900
80914930935
80914940945
80914950955
80914960980
80914960985
80914960990
80914970940
80914970955
80914980935
80914980945
80914980955

Barrel No. 4 Assembly
80914200940

Barrel No. 3 Assembly
80914400940

Barrel No. 2 Assembly
80914600940

Barrel No. 1 Assembly
80914800940

Ring No. 3 Assembly
80914300975

Ring No. 2 Assembly
80914500935

Ring No. 1 Assembly
80914700995

LH2 Tank Assembly
80914090960
80914000000

FAILURE HISTORY:

Current data on test failures, unexplained anomalies and other failures experienced during ground processing activity can be found in the PRACA data base.